Effect of late weaning and use of alternative cages on performance of does, suckling and fattening rabbits under extensive reproductive management

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Keywords:
Performance
Platform
Rabbits
Weaning age

A B S T R A C T

The effects of the combined use of long lactation periods (46 days) with alternative cages on the reproductive and growth performance of 104 rabbit does and their litters during five consecutive reproductive cycles were studied. Half of does were housed in conventional polyvalent cages (39 cm × 100 cm × 30 cm) and the other half in alternative polyvalent cages (39 cm × 100 cm × 60 cm), with a raised platform. Half of the rabbit does in each type of cage were weaned at 32 and the other half at 46 days after parturition. Longer lactation negatively affected the body weight ($P < 0.001$), fat and energy content ($P < 0.05$) of rabbit does at the end of the lactation period, but this effect decreased with the number of parturitions. Fertility, prolificacy and doe mortality were not affected by lactation length. Late weaning led to higher litter size (by 8.9%) and litter weight (by 11.3%) at the end of growing period ($P < 0.001$) and lower feed conversion ratio per cage during the experimental period (13.5%) than weaning at 32 day ($P < 0.001$). These results were paralleled by lower mortality (12.6 vs. 17.6%; $P < 0.01$) of young rabbits weaned later during the overall experimental period. Differences in performance as a result of different weaning ages were only observed during cycles with worst health status (third and fifth cycles) in which late weaning decreased mortality. Type of cage did not affect doe body weight and body condition, mortality, fertility, prolificacy and litter size during the five reproductive cycles. Nevertheless, at day 21 litter weight and feed conversion ratio between 3 and 21 day were 4.2% higher ($P < 0.01$) and 5.0% lower ($P < 0.05$), respectively, in animals housed in alternative rather than in conventional cages. Alternative cages also led to heavier litters at 59 days ($P < 0.01$). It was concluded that the combined use of longer lactations and cages with higher available surface with a raised platform could be alternatives to improve animal welfare in farmed rabbit.

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1. Introduction

The requirements of farmed rabbit does have increased, because of intensification of the reproductive rhythms leading to a wide overlapping between lactation and gestation, and genetic selection programs focused on a higher productivity (Pascual, 2010). Limited dietary intake, mainly in primiparous does, leads to a body energy deficit (Xiccato and Trocino, 2010), decreasing the productivity of does and impairing the general health status of the farm (Pascual et al., 2006). Thus, the replacement rate of does is at present around 100–120% in commercial rabbit farms (Coutelet, 2011; Sánchez del Cueto et al., 2012). It has been reported by several authors (Cervera et al., 1993; Xiccato et al., 2005) that a strategy to improve the reproductive life of the rabbits does could be a delay of the insemination postpartum, reducing body energy deficit, increasing fertility and improving welfare of the rabbit does. However, because the theoretical maximum number of parturitions per year and per doe decreases, an extensive reproductive management program could impair the profitability of rabbit farms compared to conventional management. Otherwise, special care should be taken to avoid excessive deposition of fat in extensive systems due to an increased length of the dry period (Castellini, 2007). On the other hand, high rates of mortality are observed in fattening rabbitries, especially since the emergence of epizootic rabbit enteropathy (Licois et al., 2006). A delay of weaning age may help to decrease fattening mortality in poor hygienic conditions (Romero et al., 2009) due to the protective role of rabbit milk against some pathogens (Gallois et al., 2007) and to the higher weight and age at weaning (Lebas 1993). Although Xiccato et al. (2005) found that longer lactations (25 vs. 21 days) can exacerbate the body energy deficit of does, a lower impact of this effect might be expected when comparing conventional with late weaning (32 vs. 46 days), because of the decrease in milk production after four to five weeks of lactation. An extensive reproductive system in combination with a long lactation period could thus be an alternative to improve the reproductive performance of does while improving young rabbit performance.

Late weaning decreases the available floor surface per animal, which results in a negative perception of animal welfare (Vanhonacker et al., 2009). One solution for maintaining or even increasing floor surface per doe with late weaning management is to use a two-floor cage including a platform inside and increasing the cage height (Finzi et al., 1996). Increasing the size of breeding cages could offer more comfortable housing and more possibilities for locomotion of rabbit does (EFSA, 2005). However, the results from the experiments conducted so far increasing cage size (horizontally or vertically) are not conclusive (Szendrő and McNitt, 2012) and the interaction of late weaning management with type of cage is not known.

The aim of this trial was to study does under extensive reproductive management, (inseminated at 25 days after parturition), the effect of combined use of late vs. standard weaning age (46 vs. 32 days) and alternative vs. conventional cages over five consecutive reproductive cycles on performance of rabbit does and growing rabbits.

2. Material and methods

2.1. Animal, housing and management

All experimental procedures were approved by the Animal Ethics Committee of the Universidad Politécnica of Madrid and were in compliance with the Spanish guidelines for the care and use of animals in research (Boletín Oficial del Estado, 2013).

The study was carried out at the Poultry and Rabbit Research Centre of Nutreco, in Toledo, Spain. A total of 104 nulliparous rabbit does (*Oryctolagus cuniculus*) and their litters from the first to the sixth parturition of a hybrid maternal line (Hy-Plus) were used. At 18 weeks of age, does were distributed randomly in four groups in a factorial arrangement with two housing systems and two weaning ages (32 and 46 days). The first artificial insemination (AI) was performed at 19.5 weeks of age and thereafter all does were inseminated at 25 days *post partum* (dpp). Non-pregnant females were re-inseminated 56 days later. To induce ovulation, does were given an intramuscular injection of 5 μg Lecirelin (FATRO S.p.A. Italy). All does were housed in naturally lighted room except for five days before and three days after AI when a photoperiod of 16 h light and 8 h dark were established with artificial lighting. At birth, litter size was standardized by cross-fostering (within each experimental group) to 7–8 or 9–11 kits in primiparous and multiparous rabbit does, respectively. At weaning, the does were moved to a clean room while their litters were kept in the cages where they were born. From the first artificial insemination, half of the rabbit does were individually housed in conventional polyvalent cages (39 cm × 100 cm × 30 cm) (Fig. 1). The other half of the animals were individually housed in alternative polyvalent cages (39 cm × 100 cm × 60 cm) with a wire platform (38 cm × 31 cm) raised 40 cm from the floor (Fig. 2). All the cages were equipped with a feeder and a nipple drinker placed in the lower level and a foot mat (perforated plastic plate) in the middle of the floor. Heating, cooling and forced ventilation systems allowed the building temperature to be maintained between 18 and 23 °C throughout the experimental period. Within each group of cages, half of the rabbits were weaned at 32 days of age (standard weaning; SW) and the other half at 46 days of age (late weaning; LW).

2.2. Feeding

Throughout the study, all does were fed ad libitum with the same commercial pelleted diet (doe feed; DF). Non-lactating does were restricted to 150 g/day until 25 day of gestation to avoid does fatness. After weaning, growing rabbits were fed with a commercial pelleted diet (growing feed; GF). Triplicate chemical analysis of DF and GF diets were performed according to AOAC International (2000) procedures, and the average composition (%, as fed) for DF and GF were respectively: moisture 10.4 and 10.3%, crude protein 17.0 and 16.3%, ether extract 3.1 and 3.0%, starch

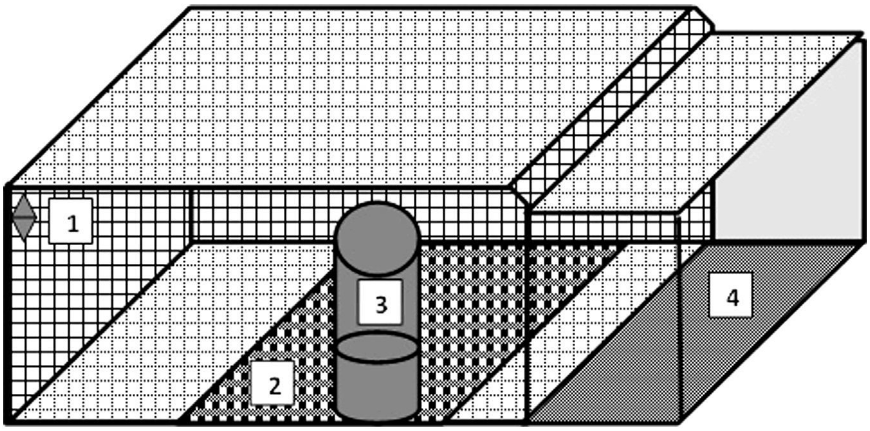

Fig. 1. Conventional cage: 1 Drinker; 2 Foot mats; 3 Feeder; 4 Nest.

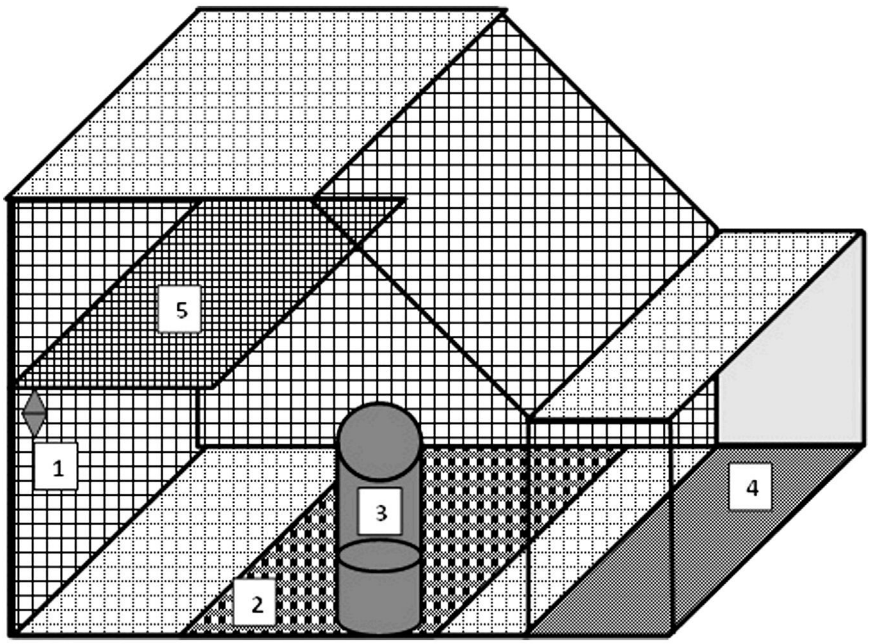

Fig. 2. Alternative cage: 1 Drinker; 2 Foot mats; 3 Feeder; 4 Nest; 5 Platform.

16.9 and 16.0%, crude fiber 14.8 and 15.4%, neutral detergent fiber 32.1 and 34.5%, acid detergent fiber 17.0 and 19.8%, lignin 5.44 and 5.50% and ash 6.2 and 7.2%. Doe and growing feeds included robenidine (60 ppm) and diclazuril (1 ppm), respectively.

2.3. Controls

During the first six parturitions, fertility, number of kits born alive and stillborn were recorded. During the first five reproductive cycles, litter size, litter weight and body weight of does at 3, 21, 32, 46 and at 59 dpp were recorded. The feed intake of does (from 3 to 21 dpp), of does and kits (from 21 to 32 and 32 to 46 dpp) and of growing rabbits (from 46 to 59 days of age) were also controlled. From 32 to 46 days, feed intake of does that had already been weaned was added to intake of their litter in order to compare it with animals subjected to late weaning. Feed conversion ratio (FCR) was calculated as the ratio of total feed intake and litter weight. Mortality of does and young rabbits was registered during the overall experimental period. The body composition of 52 does was calculated during their first three cycles by bioelectrical impedance analysis (BIA) according to multiple regression equations described by Pereda et al. (2007) to estimate moisture, protein, fat and energy content in relation to live body weight. This technique is based on measuring the resistance and reactance of the body when a weak alternating current is passed through it.

2.4. Statistical methods

Productive and reproductive traits were analysed in a completely randomized design by using a mixed model with repeated measures (MIXED procedure of SAS, 2008), with type of cage and weaning age as fixed effects and cycle as the repeated term. Lactating does were considered as the experimental unit. Several covariance structures were tested and selected according to the Sawa Bayesian information criterion. When the interaction of main effects was significant, a *t*-test was used to make pairwise mean comparisons. Means were considered significant different at $P < 0.05$. Mortality of young rabbits and fertility of does were analysed by using generalised linear mixed model with repeated measures (GLIMMIX procedure of SAS, 2008) and mortality of does during whole experimental period by using a generalised linear model (GENMOD procedure of SAS, 2008). In both cases, the statistical analysis was carried out using a binomial distribution and the logit function for maximum likelihood estimation. Values of binomial traits shown in tables were transformed using logit function.

3. Results

3.1. Body weight and body composition of does

Body weight (BW) of does increased from the first to the third cycle (4619 vs. 4868 g, $P < 0.001$) and afterwards remained stabilized. Body composition (BC) of does was also affected by the number of reproductive cycle ($P < 0.001$). At the time of the first parturition, fat and energy content were higher than at the second and both increased by third parturition (fat: 10.5, 4.26, and 8.41%; energy: 914, 605 and 795 kj/100 g, respectively). At 32 dpp, these traits were lower in the first than in the second and third cycle (fat: 5.18, 9.50 and 8.20%; energy 641, 838 and 769 kj/100 g). Moisture content was always negatively related to fat content (at parturition: 6.53, 7.26 and 6.81% and at 32 days: 7.22, 6.75 and 6.93%, respectively).

The effect of weaning age and type of cage on BW, body weight gain (BWG) and BC of does at different points of lactation phase is shown in Table 1. No significant interactions were observed between weaning age and cage type in any traits. At 32 and 46 dpp through the first five cycles, BW of does weaned later were 3.5% ($P < 0.05$) and 6.5% ($P < 0.001$) lower than does weaned at 32 days, respectively. Body weight gain from 3 to 32 and 3 to 46 dpp were also affected by weaning age ($P < 0.01$ and $P < 0.001$, respectively). In LW group it was lower by 40.7 and 76.2% than in the SW group. However, from 3 to 32 days the difference between LW and SW was only significant during the second and the fourth cycle ($P < 0.01$). Weaning age of kits had no effect on doe BW at 3 and 21 dpp, BWG from 3 to 21 dpp or from 3 dpp to three days after the next parturition. Weaning age in the first three cycles affected BC at 46 dpp. LW does had higher moisture content (4.8%), and lower fat and energy content (38.6 and 18.7%, respectively) than SW does ($P < 0.05$). However, the difference between LW and SW does for fat and energy content decreased from 4 to 1.7% and from 184 to 80 kj/100 g respectively, with the number of parturition (Fig. 3). At 3 and 32 dpp no significant differences between LW and SW for BC traits were observed.

Type of cage had an effect on BWG from 3 to 21 dpp ($P < 0.05$), reaching higher values animals housed in alternative than in conventional cages (227 vs. 180 g; Table 1). However, BW, BC and BWG throughout the experimental period were not affected by type of cage.

3.2. Rabbit doe and litter performance

The fertility depended on cycle number ($P < 0.001$) with values from the second, third and fourth cycles lower than the other cycles (96.2, 80.0, 85.4, 84.9, 96.8 and 95.6% from first to sixth parturition, respectively). The mortality of does and young rabbits from 3 to 59 days of age were low (14.6 and 17.4%, respectively). Mortality of kits depended on cycle ($P < 0.001$), as mortality in the third and fifth cycles was higher than in the other cycles (29.6 vs. 9.17%, respectively) (Fig. 4). Litter size born was also affected by cycle ($P < 0.001$), since it increased from 8.37 in primiparous does up to 12.3 in multiparous. Litter size at 59 day, during the first, third and fifth cycles was lower ($P < 0.001$) (Fig. 5) than during the second and fourth cycles (7.08, 8.01, 7.40, 9.06, and 6.60 rabbits per cage, from the first to the fifth cycle, respectively). Individual BW of kits during the first cycle was lower than later litters but at 59 days of age, the highest and lowest values were observed in first and the fifth cycles, respectively (2305 vs. 1853 g).

Table 1
Effect of weaning age and type of cage on body weight and body composition of does at different points of lactation phase.

Type of cage (C)	Conventional		Alternative		SEM[b]	*P*-value		
Weaning age[a] (W)	SW	LW	SW	LW		W	C	WxC
Doe body weight[c] (g)								
3 d	4699	4540	4686	4669	63	0.166	0.357	0.259
21 d	4903	4693	4924	4887	66	0.180	0.165	0.196
32 d	4906	4649	4903	4816	70	0.016	0.247	0.232
46 d	5021	4597	4950	4728	68	< 0.001	0.664	0.175
Does body weight gain[c] (g)								
3–21 d	203	156	240	213	24	0.131	0.046	0.678
3–32 d	213	114	219	142	29	0.004	0.560	0.722
3–46 d	330	72	259	68	29	< .0001	0.189	0.247
3—Next parturition	49.5	26.4	49.7	40.4	25.1	0.520	0.776	0.784
Body composition[d]								
Moisture (%)								
3 d	67.6	69.4	696	68.2	1.01	0.834	0.692	0.136
32 d	69.1	70.4	69.2	69.9	1.03	0.333	0.846	0.731
46 d	69.5	72.1	70.4	74.2	1.26	0.016	0.236	0.644
Protein (%)								
3 d	18.0	18.1	18.0	18.1	0.08	0.322	0.762	0.948
32 d	17.9	17.9	18.0	18.0	0.09	0.968	0.363	0.735
46 d	17.8	18.1	17.8	17.7	0.19	0.739	0.443	0.337
Fat (%)								
3 d	8.72	7.16	7.02	7.99	0.97	0.763	0.654	0.202
32 d	8.15	7.01	8.02	7.34	0.96	0.352	0.915	0.809
46 d	7.78	5.30	6.94	3.74	1.16	0.020	0.309	0.761
Energy (kj/100 g)								
3 d	817	743	735	791	43.2	0.827	0.693	0.138
32 d	775	715	769	740	43.5	0.315	0.830	0.722
46 d	746	631	707	551	53.3	0.015	0.273	0.705

[a] SW: standard weaning (at 32 d), LW: late weaning (at 46 d).
[b] Standard error of the least squares means (n=26).
[c] Values are means of the first five cycles.
[d] Values are means of the first three cycles.

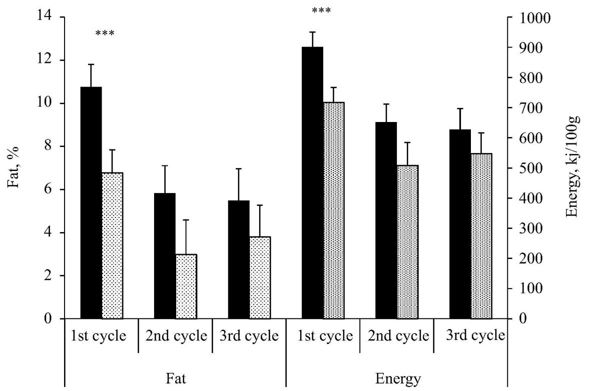

Fig. 3. Fat and energy body content of the body at 46 days after parturition of does subjected to standard (■) and late weaning (⬚) throughout the three first reproductive cycles. Each data point is the least squares mean (LSM) ± standard error of means. Level of significance: ***=$P<0.001$.

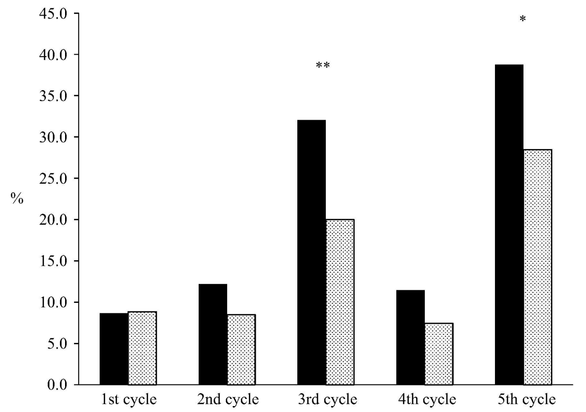

Fig. 4. Effect of standard (■) and late weaning (⬚) on mortality of young rabbits from 3 to 46 days of age throughout the five reproductive cycles. Level of significance: **=$P<0.01$; *=$P<0.05$.

The effect of weaning age and type of cage on reproductive traits, mortality and growth of young rabbits is shown in Table 2. No significant effects of treatments on fertility, doe mortality, number of kits born alive and dead during the overall experimental period were observed. Increasing weaning age from 32 to 46 dpp led to a decrease of mortality during the period from 32 to 46 days ($P<0.01$). Overall mortality was higher in animals weaned at 32 than at 46 days ($P<0.01$), but the effect was higher during the third and fifth cycles, i.e. when the highest mortality rates were observed (Fig. 4). At 46 and 59 days of age litter size in LW was 5.3 and 8.9% higher ($P<0.001$) than in SW group, respectively; however, at 59 days the difference between SW and LW was only significant at the third and fifth cycles ($P < 0.001$) (Fig. 5). From 32 to 46 and from 46 to 59, BWG of young rabbits weaned at 46 days was 5.8 g/day higher ($P < 0.001$) and 4.4 g/day lower ($P < 0.001$) respectively, than in rabbits weaned at 32 days. Litter weight at 59 dpp was thus 11.3% higher in LW than in SW ($P < 0.001$), though weaning age had no effect during the first and fourth cycles (Fig. 6).

There was no effect of type of cage on young rabbit mortality and litter size. At 21, 32, 46 and 59 days of age, animals housed in alternative cages had 5.4 ($P < 0.01$), 3.6 ($P < 0.05$), 4.7 ($P < 0.05$) and 6.7% ($P < 0.01$) higher litter weights than animals housed in conventional cages, respectively. Animals housed in alternative cages also had higher individual BW at 21(by 4.2%; $P < 0.05$), 46 (by 3.5%; $P < 0.01$) and 59 days of age (by 3.6%; $P < 0.001$) than in conventional cages.

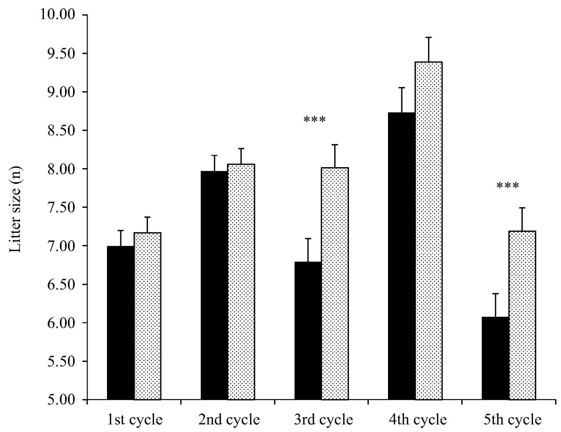

Fig. 5. Effect of standard (■) and late weaning (▒) on litter size at 59 days of age throughout the five reproductive cycles. Each data point is the least squares mean (LSM) ± standard error of means. Level of significance: ***=$P < 0.001$.

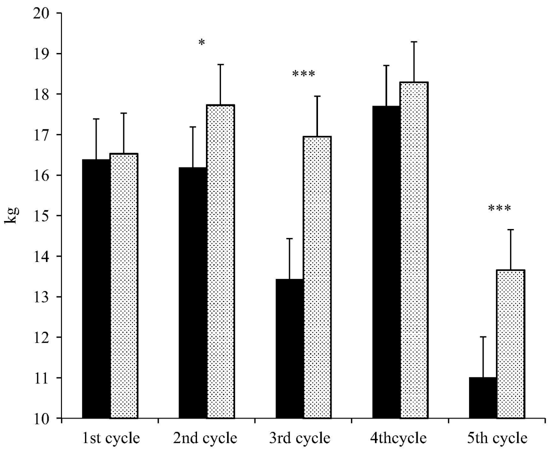

Fig. 6. Effect of standard (■) and late weaning (▒) on litter weight at 59 days of age throughout the five reproductive cycles. Each data point is the least squares mean (LSM) ± standard error of means. Level of significance: ***=$P < 0.001$; *=$P < 0.05$.

Table 2
Effect of weaning age and type of cage on reproductive parameters, mortality of animals and litter traits.

Type of cage (C)	Conventional		Alternative		SEM[b]	*P*-value		
Weaning age[a] (W)	SW	LW	SW	LW		W	C	WxC
Fertility[c] (%)	93.9	91.9	87.9	92.9	–	0.678	0.339	0.116
Doe mortality[d] (%)	16.0	11.5	19.2	11.5	–	0.390	0.845	0.845
Total born, n[c]	11.4	11.8	11.9	11.4	0.4	0.835	0.872	0.257
Stillborn, n[c]	1.35	0.99	1.00	0.85	0.20	0.219	0.240	0.618
Young rabbit mortality[e] (%)								
3–21 d	4.75	3.90	4.66	4.41	–	0.585	0.822	0.762
21–32 d	3.47	1.40	2.15	2.27	–	0.228	0.996	0.135
32–46 d	3.90	0.94	2.80	1.10	–	0.003	0.792	0.490
46–59 d	5.20	3.83	2.88	3.09	–	0.756	0.262	0.214
3–59 d	20.0	11.9	15.2	13.3	–	0.003	0.372	0.053
Litter size[e] (n)								
3 d	9.29	9.22	9.21	9.38	0.09	0.616	0.627	0.163
21 d	8.82	8.84	8.88	8.91	0.13	0.870	0.634	0.965
32 d	8.47	8.70	8.74	8.63	0.13	0.655	0.455	0.197
46 d	8.03	8.70	8.32	8.51	0.13	< 0.001	0.739	0.096
59 d	7.07	8.04	7.56	7.89	0.17	< 0.001	0.321	0.096
Litter weight[e] (g)								
3 d	817	842	825	848	15	0.077	0.624	0.942
21 d	2921	3040	3145	3135	50	0.275	0.002	0.200
32 d	6294	6666	6749	6678	112	0.184	0.040	0.051
46 d	10679	12480	11557	12686	211	< 0.001	0.012	0.115
59 d	14161	16396	15730	16866	376	< 0.001	0.008	0.147

[a] SW: standard weaning (at 32 d), LW: late weaning (at 46 d).
[b] Standard error of the least squares means ($n=26$).
[c] Total doe mortality during six consecutive parturitions.
[d] Values are means of the first six parturitions.
[e] Values are means of the first five cycles.

Table 3
Effect of weaning age and type of cage on feed intake and feed conversion ratio during the first five reproductive cycles.

Type of cage (C)	Conventional		Alternative		SEM[b]	P-value		
Weaning age[a] (W)	SW	LW	SW	LW		W	C	WxC
Feed intake (g/d per cage)								
3–21 d	369	371	380	385	6	0.611	0.053	0.886
21–32 d	649	656	663	659	9	0.888	0.357	0.565
32–46 d[c]	836[B]	972[A]	955[A]	972[A]	16	< 0.001	< 0.001	< 0.001
46–59 d[d]	957	996	1036	1036	23	0.389	0.013	0.403
3–59 d[d]	687[B]	731[A]	743[A]	745[A]	9.9	0.023	< 0.001	0.040
Feed conversion ratio								
3–21 d	3.28	3.13	3.02	3.07	0.06	0.436	0.011	0.087
3–32 d	2.48	2.30	2.30	2.34	0.06	0.227	0.216	0.055
3–46 d[c]	2.79	2.32	2.61	2.24	0.08	< 0.001	0.081	0.499
3–59 d[d]	3.30	2.82	3.09	2.71	0.09	< 0.001	0.086	0.575

[A, B] Means in the same row with unlike superscripts differ ($P < 0.05$).
[a] SW: standard weaning (at 32 d), LW: late weaning (at 46 d).
[b] Standard error of the least squares means ($n = 26$).
[c] Feed intake of does and growing rabbits was included.
[d] Feed intake of does from 46 to 59 days was not included.

3.3. *Feed intake and feed conversion ratio*

Feed intake (FI) of lactating does and kits up to 32 days after parturition was lower during the first ($P < 0.001$) than during the other reproductive cycles (420 vs. 497 g/day). When the fattening period was also considered, FI days was lower during the first and fifth cycles than during the others (679 vs. 759 g/day; $P < 0.001$). Feed conversion ratio was affected by cycle. From 3 to 32 days of lactation, FCR was higher in the first than in the other cycles (2.52 vs. 2.32; $P < 0.001$). However, up to 59 days, values were lower during the first, second and fourth cycles than during the third and fifth cycles (2.72 vs. 3.37; $P < 0.001$).

The effect of treatments on FI and FCR through the first five cycles is shown in Table 3. FI was higher at 46 dpp with the later weaning age ($P < 0.001$) and over the whole experiment ($P < 0.05$) than with the earlier weaning age. Weaning age had an effect on FCR ($P < 0.001$). During the experimental period lower values were observed in the LW than in the SW group (2.77 vs. 3.20).

Type of cage affected FI during the periods from 32 to 46 ($P < 0.001$), 46 to 59 ($P < 0.05$) and from 3 to 59 days of age ($P < 0.001$). Animals housed in alternative cages consumed 6.6, 6.1 and 4.9% more feed than those housed in conventional cages, respectively. However, from 32 to 46 days and during the whole period, the lower values in conventional cages were only observed in animals weaned at 32 days. The FCR from 3 to 21 dpp was 5.0% ($P < 0.05$) lower in alternative than in conventional cages.

4. Discussion

4.1. *Weaning age*

Lactation requires a great energy expenditure of the rabbit doe and is closely related to some variables as body condition and fecundity. Moreover, animals with longer lactations could have a higher susceptibility to diseases, as they show a fewer number of total lymphocytes at the end of lactation (Guerrero et al., 2011). A higher body energy deficit in does subject to longer lactations was observed in several trials where early and standard weaning ages (21/23 vs. 32/35 days) were compared (Feugier and Fortun-Lamothe, 2006; Xiccato et al., 2004). In the current trial, though the effect of an extended lactation period led to a lower BW and body energy of does at 46 dpp, this effect decreased from the first to the third reproductive cycle. Primiparous does are more sensitive to energy deficits than multiparous does, where no relevant energy deficit seems to occur during lactation phase (Pascual et al., 2013). This result is probably due to limited intake capacity, as a relatively lower FI was observed in the first cycle during the lactation period. Several authors demonstrated a relationship between feed and energy intake and body energy deficit in lactating and pregnant does from their first to second parturition (Fortun-Lamothe and Lebas, 1996; Xiccato et al., 1995). Despite the lower body energy observed in LW does at 46 days of lactation, the recovery time from weaning to the next parturition was enough to compensate the BW and body energy at the next delivery. This ability to recover body reserves could explain the absence of weaning effect in the current trial on fertility and mortality of does during the five breeding cycles, as well as on BWG of suckling rabbits and FI until 21 or 32 days, which indicates similar milk production in both treatments. These results could also be related to the extensive reproductive rhythm used in the current trial (AI 25 dpp). Previous work showed a significant improvement of BC, energy balance and fertility using extensive reproductive rhythm, because it is better adapted to the physiology of rabbit does (Castellini, 2007). Thus, when combining an extensive reproductive rhythm with LW, the long recovery time after weaning (10 days) and the non-simultaneity of the main milk production phase (up to 21 days) with pregnancy could be as important as an adequate body energy content after weaning. In this way, Pascual et al. (2013) suggested that a short recovery time after weaning and a large mobilization occurring at late pregnancy could be more responsible for a negative balance of lactating-pregnant rabbit does during their first reproductive cycle than the lactation effort. Martínez-Vallespín et al. (2012) did not observe a negative effect of LW (42 dpp) on fertility rate in multiparous does when compared with conventional management (AI at 11 dpp and weaning at 28 dpp). An even higher fertility rate was obtained in primiparous does subjected to LW. Nonetheless, they found a negative long term effect on litter weight mainly when extensive management was combined with a less concentrated diet around weaning. In contrast, a trend towards a higher kit body weight at 3 dpp with LW was observed in the current trial, which could be related to differences in feed intake during late gestation (data not recorded). According to Quevedo et al. (2006), one of the factors conditioning the energy intake after weaning is the BC of the female, and an increase of energy intake that leads to a heavier litter. Therefore, in the present trial it can be presumed that there was an increase in feed intake by LW does after weaning, as lower energy and fat content were observed at that moment. This would coincide with the late gestation phase, when the growth rate of the fetuses is higher (Mocé et al., 2004), affecting the body weight of kits after parturition. On the other hand, the difference between the litter weight of SW and LW at the third dpp could be also due to the recovery time after weaning in the SW group (24 vs. 10 days, respectively), as a possible overfattening with lengthy dry period could have negatively affected fetal growth, with a higher risk of metabolic diseases of does as pregnancy toxaemia (Rosell, 2000). Other studies reported a higher risk of overfattening in does inseminated post-weaning (26 dpp) which impaired the fertility rate (Castellini et al., 2006).

Regarding growing rabbits, in the present trial the BW at 46 day of late weaned animals was higher than rabbits weaned at 32 day ($P < 0.001$) but was not different at the end of the growing period. This result could be related to milk intake during late lactation phase. According to Peaker and Taylor (1975), milk production at 32 days is still relevant. Lebas (1969) found that the milk intake of kits during the sixth week of lactation was around 9.7% of the total milk intake. The difference at 46 day as compared to weaning could also be related to a negative impact of feed switching of rabbits weaned at 32 days and high energy content of lactation feed. Romero et al. (2009) also found higher BWG with late weaning. However, they did not observe the compensatory effect during the second growing period, probably due to a high incidence of epizootic rabbit enteropathy and the positive effect of LW reducing mortality. A numerical reduction of mortality with longer lactations was also observed by Martínez-Vallespín et al. (2012). In the present trial, late weaning decreased mortality of growing rabbits but only during cycles with worse health conditions, (second, third and fifth cycles). During these cycles, higher litter size, litter weight, FI per cage and lower FCR with late weaning were observed. This fact could be related to antibacterial effects of maternal rabbit milk found by several authors (Gallois et al., 2007; Marounek et al., 2002). Furthermore, a slower transition period from milk to feed intake could help to avoid gastrointestinal disorders caused by the sudden shift from milk to exclusive solid feed intake (Fortun-Lamothe and Gidenne, 2000; Maertens and De Groote, 1990).

Otherwise, late weaning decreases the available floor surface per animal, which results in a negative perception of animal welfare (Vanhonacker et al., 2009). However, the positive effect that late weaning seems to have on mortality under environments with high health risk, can be associated to an improvement of animal welfare, even in conventional cages with lower available floor surface.

4.2. *Type of cage*

As pointed out by Szendrő and Dalle Zotte (2011), effects of increasing the size of cages (horizontally or vertically) are not conclusive. In the current trial, the type of cage did not affect fertility, BW, BC and mortality of does, prolificacy or litter size throughout the overall experimental period. Most of these results were similar to those observed in literature (Bignon et al., 2012; Mikó et al., 2012; Mirabito et al., 2005). However, Rommers and Meijerhof (1997) found higher numbers of kits born alive and weaned using higher cages. Barge et al. (2008) and Masoero et al. (2003) found an impairment of fertility with two-floor cages.

The growth of newborn rabbits depends mainly on the quantity and quality of the milk ingested from the does, until at least around 20–25 days of age, when the consumption of solid feed starts (Gidenne et al., 2002). During this period of milk dependency, higher BW and BWG of young rabbits were observed in the current trial in alternative cages, contrary to the results of Masoero et al. (2003), but in agreement with observed by Barge et al. (2008) and Mikó et al. (2012). Results from the current study suggest higher milk production of does housed in alternative cages, explaining the higher BWG of does observed during first lactation period. Milk production could be associated with stress level through adrenergic mechanisms. According to Alfonso-Carrillo et al. (2014) the platform of the alternative cages is used as an escape by rabbit does in the lactation phase, decreasing the stress caused by the kits at certain times, which could explain the increase of milk production in this type of housing. Moreover, Mirabito (2003) found that the nursing attempts by kits did not decrease in cages with platforms. The higher productivity should imply an increase of the nutrient requirements of does, which could be related to the increase of FI observed during this period in alternative cages. Higher feed consumption might also be explained by an increase of exercise with the use of platform, as it is used frequently throughout the day (Alfonso-Carrillo et al., 2014).

Regarding young rabbit mortality, Barge et al. (2008), observed lower kit mortality from 20 to 35 days using a platform in the cages in only one of the two strains studied. Mikó et al. (2012) found a positive tendency of cage enlargement and height with a platform on mortality up to 32 days. Although, in the current trial, the effect of type of cage on mortality of young rabbits up to 32 days was not significant, mortality during the overall growing period of animals weaned at 32 days was numerically higher in conventional than in alternative cages. This result could be due to an easier spread of disease in cages with less available area, because of the more frequent contact among animals in the same cage.

Thus, in the growing period, an increase of the size of the area available in alternative cages led to an increase of final BW, litter weight and FI of the animals. In agreement, Lang and Hoy (2011) found higher BWG during the entire growing period in cages with platforms than in cages without them but that difference was only observed in two of four rounds. Other authors also found that the elevated platform resulted in a higher FI and BWG from 29 to 46 days of age (Maertens et al. 2004) or higher BW at 36 and 63 days of age (Jehl et al., 2003). Nevertheless, in both trials, at the end of fattening period (around 70 days), performance was not affected significantly by the use of platforms. Matics et al. (2014) studied different housing conditions with or without elevated platforms, and observed an impairment of growing performance with platform covered with straw-litter, but no effect was found when a wire net platform was used. Postollec et al. (2008) showed a significant reduction of BWG in enriched cages with elevated platforms; however, these authors used larger cage compared with the alternative cages used in the current trial, and physical activity could be greater. Princz et al. (2008) did not find any effect of height of the cage (20, 30, 40 cm or open top) on BWG, FI or FCR in fattening rabbits aged 5 to 11 weeks. Thus, the results from the current trial could be less related to the height of the cage than to a decrease of density of animals, through the increase of surface with the use of the platform (19.9 vs. 15.5 rabbits/m^2; 40.1 vs. 32.1 kg/m^2, in conventional and alternative cages). This is in agreement with the impairment of growth performance observed by Aubret and Duperray (1992), Lambertini et al. (2001) and Villalobos et al. (2008) with increased densities of animals. Thus, Szendrő and Dalle Zotte (2011), concluded in a review about the effect of housing conditions in growing rabbits that the optimal stocking density was 16–18 rabbits/m^2 (40–45 kg/m^2).

5. Conclusions

According to the results of the current study, when facing situations with high sanitary risk after weaning, the combined use of extensive reproductive rhythms with long lactations and alternative cages increasing available surface with a raised platform could be an alternative to improve animal welfare, decreasing mortality and increasing performance of growing rabbits without detriment to the reproductive traits of rabbit does. However, the economic impact of implementing this management procedure and housing system on the profitability of rabbit farms should be taken into account.

Conflict of interest statement

The authors wish to confirm that there are no known conflicts of interest associated with this publication.

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